LEARNING CHEMISTRY BY INDIVIDUALLY GUIDED SYSTEM OF INSTRUCTION

(IGSI)

(SECONDARY STAGE)

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FOREWORD

The National Policy on Education—1986 (NPE—86) required the school curriculum to be child centred. It stresses more on learning than teaching. The implementation of NPE—86 requires updating of our present curriculum and teaching practices. Consequently, the National Council of Educational Research and Training is in the process of developing new instructional packages, prototypes and exemplary materials. Some new methods of instruction are also being developed for all school stages. Noteable among these is the Individually Guided System of Instruction (IGSI) which comprises lecture for only 25% of the class time; self paced, individualised, student tutored and mastery systems.

In the IGSI, it is the student who has to take initiative in the learning process and this self-initiated learning is evaluated and feedback is given. It encourages persistence in the face of failure to solve problems. There are several other creativity promoting elements in the IGSI. It has now proved to be a viable alternative to the method of instruction in use.

The objective of writing this module is to acquaint the teachers and teacher educators with the technology of IGSI. Two sample self-study units along with the mastery assessments, which are used in implementing IGSI in secondary level chemistry course, are also included.

The IGSI for secondary stage chemistry was developed in the Department of Education in Science and Mathematics by Prof. R.N. Mathur and Dr Brahm Prakash who deserve special appreciations. I am thankful to Prof R.N. Mathur for coordinating this programme and working unrelently in introducing innovations in school education My special thanks are due to Dr. Brahm Prakash, Reader, for introducing the present innovation in imparting chemistry instruction and for editing this module and giving it the shape that it has.

I will welcome any suggestion for the improvement of this module.

P.L. Malhotra
Director
National Council of Educational
Research and Training, New Delhi

PREFACE

The programme of Individually Guided System of Instruction was taken up in this department with a view to individualise science instruction at secondary stage This system comprising lectures for about 25% time, guided self study, self-paced, mastery and tutorial help has been developed wherein application has been emphasised using guidelines followed in ancient Indian schools of philosophy A method of learning suggested in nearly 5000 years old Indian literature is given below :

आचार्यात पादमध्यन्ते
    पादम शिष्य: स्वमेधया ।
पादम स्वब्रह्मचारिण्योश्य·
    पादम काल क्रमेणवा ।।

The translation of this quotation is as follows :

Learn one-fourth from the teacher
    one fourth by self study
One fourth from fellow pupils
    and one fourth while applying
    knowledge from time to time

In addition, the findings of recent researches in the field of education and psychology have been used to develop this system of instruction.

The present system was tried out in a number of schools in collaboration with the concerned teachers. The materials required for implementation of this system were developed in a workshop These were revised on the basis of feedback received from students and teachers. I thank the teachers for their full cooperation in trying out this system and providing feedback and suggestions from time to time. I also thank the participants of the workshop for their untiring efforts in the development of units and mastery assessments. I especially thank Prof R.N. Mathur who coordinated this programme and was actively involved in the development of this novel system of instruction

My thanks are also due to Professor B. Ganguly, Head, DESM, for his keen interest and valuable suggestions in the development of this module.

BRAHM PRAKASH
Reader
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March, 1988

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Individually Guided System of Instruction (IGSI)
For Secondary Classes

Introduction

The New Education Policy-86 envisages a drift from the traditional lecture method to an approach that has a focus on learner It has now been realised that teaching is not telling, memorizing is not learning, and reproducing something in the examination is not an evidence of understanding The teaching should stress on developing habit of study throughout the life of a person. What is needed is to inculcate the spirit of enquiry in the students They should develop self confidence and the habit of learning to learn. Individually Guided System of Instruction is an appropriate learning strategy which suits the need of the present time In this, the learner is encouraged to take initiative in learning and carry out self assessment The teacher assumes the role of learning facilitator. The instruction caters to the needs of each individual

Materials in IGSI

Units · The contents of a course are divided into units such that a unit takes 6-8 periods for completion. Each unit is provided with a "Study Guide" which contains an introduction to the unit, objectives of the unit, suggested procedure to achieve the objectives, solved examples, assignment and self assessment,

Teacher's Guide : There is a teacher's guide for every unit. It contains the core portion of the unit and suggestion regarding domonstrations to be shown in the class.

Mastery Assessments :- There are five mastery assessments of each unit.

Main Features of IGSI :- The main features of IGSI are briefly described below.

(a) Presentation of the Core Portion

This will be done by the teacher in every unit, utilising roughly 25% of the time The core portion comprises major concepts, demonstration and other activities involving direct interaction between the teacher and the learners.

(b) Individualised instruction

Six to eight learners are assigned to a tutor who assists them (one at a time) through this course. (In the classroom situation this responsibility will be shouldered by senior students or fast learners of the same class who are selected on the recommendations of the faculty.) The tutor will do this voluntary community service as a part of his SUPW activity.

The educated persons from community such as house-wives, retired persons, researchers from universities may also act as tutors. This will encourage the involvement of community in the process of education. In order to ensure a learner's steady progress it is essential to have a rapport between the learner and his tutor.

(c) Tutor guided self study

The learner works with a tutor who guides him. The teacher will also be available to assist the learner to progress. The initiative in this course rests with the learner.

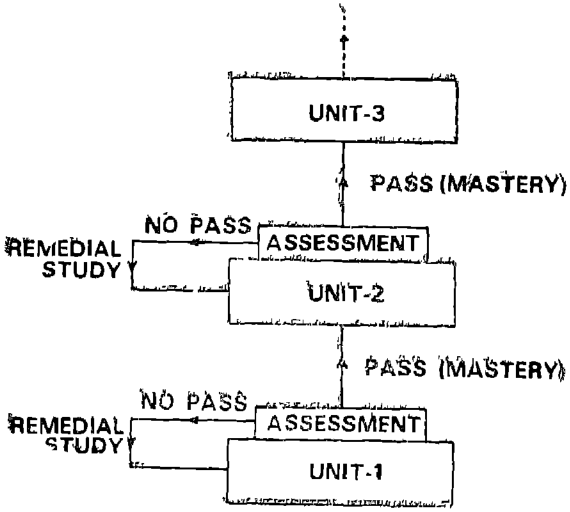
(d) Self-pacing

The learner progresses in this course at a pace depending upon his ability. He can fix a work schedule for himself which would ensure steady progress. He is advised to complete a unit before presentation of the next unit He will be cautioned in case he neglects his works and lags behind. A graph showing the needed individual pace to complete all the units in time may be devised by every learner.

(e) Mastery learning

A learner will be permitted to take a new unit only after he has shown mastery of the preceding unit However, he will be permitted to attend the presentation by the teacher on core portion of the next unit even if he has not cleared the preceding unit. To achieve the objectives stated in the 'Study

Guide', he may follow the procedure recommended and take tutor's help, if necessary.



(f) Instant reward

The unit tests are graded in the presence of the learner immediately after he has taken them. If a written answer is not satisfactory, he may be asked to explain what he wanted to convey. If the verbal explanation exhibits complete understanding of a certain problem, he may be given a pass despite the fact that the written answer is wrong.

A unit test will be graded as 'Pass' If he demonstrates mastery and 'No Pass' if he does not.

The Mechanics of the Course

(a) The learner works to achieve the objectives stated in the study guide. He may follow the steps suggested in the procedure or any other steps that suits him better.

(b) When he feels that he has mastered the contents of a unit he may ask his tutor for a test. He may sit at a place specified for the purpose. After completion he should go to the tutor for grading.

(c) The tutor will grade his test immediately in his presence and give a feedback He may ask for clarification of the answer, if necessary. (The tutor will keep the answer sheet for review by the teacher. The learner may see his tests and answer sheets which will be kept in a folder, before taking another test on a unit.)

Grading Technique-An illustration (For actual class-room situation)

In this course total marks will depend on the number of units passed and performance in examination. The computation procedure is given below :

First Term

There will be no term examination. Marks will depend only on the number of units passed Five units, each carrying ten marks, are supposed to be completed in the first term.

No. of units passed	Marks (out of 50)
5	50
4	40
3	30
2	20
1	10
0	0

However, if one finishes all the five units early he is advised to continue working on second term units so that he may finish them early.

Second Term

In the first and second terms one is required to finish a total number of eleven units. In addition, there will be a common examination at the end of the second term This examination will cover all the eleven units. Those who clear all the units early, may concentrate on other assignments.

Each unit will be worth 10 marks. The common examination will be worth 40 marks. If a student completes all the eleven units he gets 110 marks on units alone. Further if he gets 40 marks in the common examination his total marks will be 110 + 40 = 150 which is also the maximum marks one can obtain On the other hand, a student who completes 8 units he gets 80/110 marks on units alone and if he gets 32/40 in the common examination, his marks at the end of the second them will be 112/150.

Unit-I
Nature and Composition of Matter-I

I. Introduction

In our day-to-day life, we see a number of substances around us. These are water, food, metals, salts, rocks, minerals, fibres, etc. New medicines are being prepared every day. Soaps, detergents synthetic fertilizers, fuels etc. are commonly used in the present age of science and technology. Besides this, we hear every day about a number of new products used either in every day life or in industry. All these products differ from one another in their appearance and properties. Yet these have one thing in common—they are all made up of atoms.

· For an effective utilization of the substances, it is necessary to have a systematic knowledge of their chemical characteristics. This knowledge has been simplified by arranging the substances into various groups on the basis of their common characteristics. This knowledge has been further systematized by representing each substance by its chemical symbol. The reactions which these substances undergo are also represented in a short form by chemical equations Thus, in this unit we shall study the classification of matter into elements, mixtures and compounds, and also learn the language of chemistry.

II. Objectives

After studying this unit, you should be able to :

1 Identify substances into elements, mixtures and compounds.

2. Write the chemical formulae of the various compounds

3. Write balanced chemical equations to represent chemical reactions.

4. Describe the significance of a chemical equation.

5. Solve problems based on chemical equations.

III Suggested Reading Material

Matter : We see water, wood, iron etc. and feel air around us. All of these occupy space and have mass. Anything that occupies space and has mass is known as matter Thus water, wood, iron and air are all different forms of matter.

1.1 Classification of Matter

Just as twenty six alphabets in English language constitute thousands of words, 105 basic or elemental substances are known to constitute matter which exists in a variety of forms Matter can be classified into three classes, namely elements, mixtures and compounds.

1.11 Elements : Substances which can not be broken down into simpler substances by ordinary means such as heating are known as elements. For example heating magnesium carbonate decomposes it into magnesium oxide and carbon dioxide. Magnesium oxide on further heating in absence of air breaks into magnesium and oxygen. But magnesium, even on strong heating in absence of air, does not break down further. Thus a stage is reached at which it is no longer possible to divide any particular substance into other substances Such substances are known as elements. Magnesium, aluminium, iron, copper, silver gold, oxygen, nitrogen, chlorine are some of the examples of elements. As the elements are the building units of all kinds of matter, the study of elements helps us to understand matter. In Chemistry, the elements are represented by the shorthand notations in a similar way in which the initials are used as shorthand notations for names. For example in M.K. Gandhi, the letters M&K represent Mohandas and Karamchand respectively. These shorthand notations in chemistry are derived from the names of elements and are known as symbols The names of some of the elements along with their symbols are given in Table 1 1.

Table 1.1

Some common elements and their symbols

S. No.	Name of the element	Symbol	Latin or German name
1.	Hydrogen	H	
2.	Carbon	C	

3.	Nitrogen	N	
4.	Oxygen	O	
5	Silver	Ag	argentum
6	Aluminium	Al	
7	Barium	Ba	
8.	Copper	Cu	Cuprum
9	Iron	Fe	Ferrum

Occurrence of Elements

Elements are found in earth in free as well as in combination with other elements. Oxygen, silicon, aluminium, iron, calcium, sodium, potassium and magnesium make up about 28% of earth's crust.

Table : 1.2

Elements in earth's crust

Element	Percentage (%)
Oxygen	46.7 ✓
Silicon	27.7
Aluminium	8.1
Iorn	5.0
Calcium	3.6
Sodium	2.8
Potassium	2.6
Magnesium	2.1

Oxygen, carbon, hydrogen, nitrogen, calcium and phosphorus are the common elements found in the form of compounds in a human body. They make up 98% of our body.

Table 1.3

Elements found in the human body

Element	Percentage (%)
Oxygen	65
Carbon	18
Hydrogen	10
Nitrogen	3
Calcium	1.5
Phosphorus	1.0

1.13 Compounds : When two or more atoms of different elements chemically combine together in a fixed proportion, they form new substances known as compounds For example , Water (H_2O) is a compound made up of two elements, hydrogen and oxygen. Similarly sugar, sodium chloride, carbon dioxide are chemical compounds. A compound has properties entirely different from those of its elements Consider water (H_2O) as an example. It is made up of two elements, hydrogen and oxygen. Hydrogen is combustible i e. it catches fire and burns with an explosive sound Oxygen supports fire. Water which is formed from the elements hydrogen and oxygen, puts off fire. Moreover hydrogen and oxygen are gases while water is a liquid.

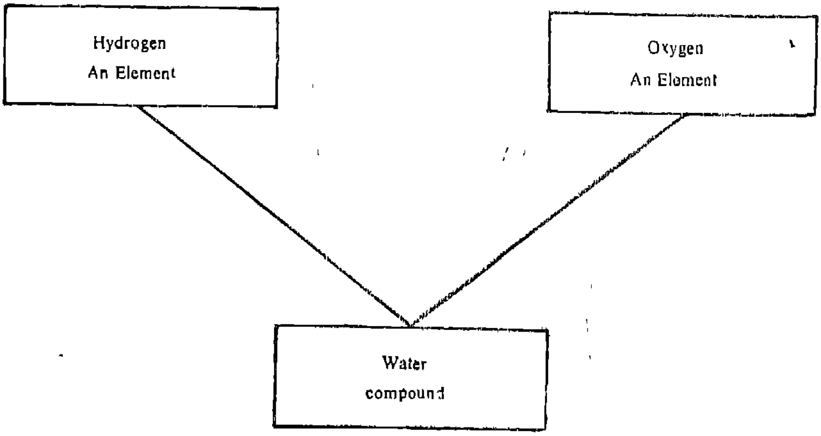


Fig. 1.1 Formation of a compound from its Elements.

1.14 Law of Definite Composition · The compound, iron suphide is formed by chemical combination of iron and sulphur We find that this compound always contains one atom of iron for each atom of sulphur. Similarly in water, two atoms of hydrogen have chemically united with one atom of oxygen to form water i e H_2O Thus we can see that the composition of every pure compound is always constant. This is the law of difinite composition. A **chemical compound always contains the same elements combined in the same ratio.** Thus in every sample of pure water, be it from tap, handpump or spring, the ratio of hydrogen to oxygen atoms is always the same i.e 2:1.

1.15 Formula of a Compound.

A formula is a shorthand notation to represent the molecule of a compound It consists of symbols of elements that form the molecule of compound Thus NaCl is the formula of sodium chloride. A Formula tells the number and kinds of atoms in the molecule of the compound Thus $C_{12}H_{22}O_{11}$, the formula for cane sugar, represents that cane sugar is composed of carbon, hydrogen and oxygen and their atoms are present in the ratio of 12 22:11. To write the formula of a compound you have to know the combining capacity of ecah element making up the compound The combining capacity of an element is known as its valency The valencies of a few elements or group of atoms are given in Table 1.4.

Table 1.4

Name	Symbol	Valency	Name	Symbol*	Valency
Ammonium	NH_4^+	+1	Carbonate	Co_3^{2-}	—2
Aluminium	Al^{3+}	+3	Chloride	Cl^-	—1
Copper	$Cu,^+$ Cu^{2+}	+1, +2	Bromide	Br^-	—1
Calcium	Ca^{2+}	+2	Chlorate	ClO_3^-	—1
Hydrogen	H^+	+1	Nitrate	NO_3^-	—1
Silver	Ag^+	+1	Oxide	O^{2-}	—2
Iron	Fe^{2+}, Fe^{3+}	+2, +3	Phosphate	$PO^3{}_4^-$	—3
Sodium	Na^+	+1	Sulphate	$SO^2{}_4^-$	—2
Zinc	Zn^{2+}	+2	Bicarbonate	HCO_3^-	—1
Barium	Ba^{2+}	+2	Hydroxide	OH^-	—1
Magnesium	Mg^{2+}	+2			
Potassium	K^+	+1			
~~Hydrogen~~	~~H^+~~	~~+1~~			

1.16 How to write the Formula of a Compound

In order to write the formula of a compound write the symbols of elements or radicals with positive charge on left side and those with negative charge on right side. The number of positive and negative charges are made equal by putting the numbers as subscripts of symbols of elements.

For example in H_2O, the subscript is 2 for H.

Example 1 : To write the formula of calcium sulphate look for the symbol of calcium and its valency from the table Similarly look for the symbol of sulphate and its valency Since calcium, Ca^{2+}, has a charge +2 and sulphate SO_4^{2-}, has a charge - 2. Thus the formula for calcium sulphate is $Ca\,SO_4$.

Example 2 . To write the formula for sodium phosphate, sodium has the symbol Na and charge +1. Phosphate has a symbol of PO_4 and charge-3. Therefore we need three sodium radicals to balance three negative charges on the phosphate radical. Thus formula for sodium phosphate is $Na_3\,PO_4$.

Examble 3 : To write the formula for aluminium sulphate, we find from the table 1.4 the symbol and the valency for aluminium to be Al and +3 respectively. Similarly for sulphate, the symbol is SO_4 and its valency is-2. In order to balance the positive charge on aluminium we need to have more than one sulphate. We can have equal positive and negative charges by having two aluminium (Total charge +6) and three sulphate (total charge—6) radicals. So the formula for aluminium sulphate will be $Al_2\,(SO_4)_3$.

We can also write the formula of compounds in the following way;

1 Write the symbols of elements or radicals present in the compound The symbols with positive charge are written on the left side and with negative charge on the right hand side.

2. The valency of the radical on left hand side is written as a subscript of the other element Similarly the valency of the radical on right hand side forms the subscript of left hand side element

3. Simplify the subscript in the simplest ratio. This ratio is the ratio in which these elements or radicals are present.

Examples

Calicum sulphate	$Ca_2 (SO_4)_2$	$CaSO_4$
Sodium Phosphate	Na_3PO_4	Na_3PO_4
Aluminium sulphate	$Al_2 (SO_4)_3$	$Al_2(SO_4)_3$

1.17 Mixture · A mixture is obtained by physically mixing two or more substances with one another The substances to be mixed may be elements, compounds or both. For example air is a mixture of gases. It contains oxygen, nitrogen, carbon dioxide and some other gases. Other examples are sea water, milk, steel etc In a mixture, as the substances are only physically mixed, they retain their original properties For example when we mix sand and sugar, an off coloured mixture is obtained. On mixing iron powder and sulphur, a brown coloured mixture is obtained When a magnet is put into this mixture, the iron particles stick to the magnet and thus get separated from sulphur. The constituents of this mixture can also be separated by shaking the mixture with carbon disulphide. Sulphur dissolves in it while iron remains insoluble.

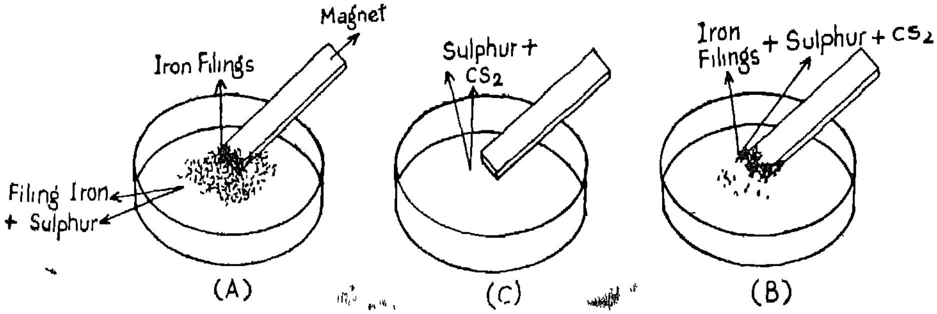


Fig. 1.3 Difference in compound and mixture.

Table 1 5

Difference between compound and mixture

	Mixture	Compound
1.	The constituents of a mixture may be present in any proportion e g. in a mixture of sugar and sand, they can be present in any proportion.	The constituents of a compound are present in a fixed proportion e g in water (H_2O), H and O are present in a ratio of 2:1.
2.	The properties of a mixture are similar to the properties of its constituents. e.g mixture of iron and sulphur shows the properties of both iron and sulphur.	The properties are entirely different from those of its constituents e g. properties of NaCl are different from sodium and chlorine.
3.	The constituents can be separated by physical means e.g. a mixture of sand and sugar can be separated by shaking with water.	The coustituents can not be separated easily. e g sodium and chlorine can not be separated easily from common salt.

Questions :

1. State and explain the law of definite composition with the help of an example.

2. Using the symbols and valencies of elements/radicals given in table 1.4, write the chemical formulae of the following compounds :

   (i) ammonium chloride
   (ii) potassium nitrate
   (iii) iron (II) sulphate
   (iv) zinc oxide
   (v) aluminium phosphate
   (vi) potassium hydroxide
   (vii) aluminium sulphate

3. Classify the following into element, mixture and compound :

(i) iron
(ii) water
(iii) ink
(iv) paper
(v) steel
(vi) ammonia gas
(vii) copper sulphate
(viii) brass

4 Fill in the blanks;

(i) A mixture has got a ... ... composition of its constituents. (fixed, variable)

(ii) The properties of a compound are...... .. . as those of its constituent elements (same, different).

(iii) Elements.. . .. . be broken down into simpler species by ordinary means. (can, Cannot)

(iv) Cl_2 is an ... .. (element, compound).

1 2 Atomic and Molecular Masses

1.21 Atomic mass

The atomic mass of an element is the mass of a single atom of that element. Since the mass in grams of the individual atoms are too small e..g the actual mass of one hydrogen atom is 1.673 x 10^{-24} gms., it is not convenient to use such figures. For convenience we use a unit called an atomic mass unit We define an atomic mass unit (abbreviated as amu) as one twelth the mass of a carbon—12 atom. A carbon—12 atom has 6 protons and six neutrons It has a mass of 12 a.m u. The atomic mass of each element has been determined It expresses the relative mass of an atom of the element compared to the assigned mass of carbon—12 atom i.e. 12.000 a.m.u. Atomic mass of magnesium is 24.3 which means that a magnesium atom is 24.3 times heavier than 1/12 of mass of carbon—12 atom. Relative masses are ratio as they do not have any unit. A list of some elements with their atomic masses is given in table 1.6.

1 22 Molecular Mass

The molecular mass of an element or a compound is the sum of the atomic masses of the atoms constituting it. The molecular mass is determined by adding together the atomic masses of all the atoms in the molecule. Thus the molecular mass of water (H_2O) is found by adding together the masses of two atoms of hydrogen and one atom of oxygen.

$$H_2O = (2 \times 1) + 16 = 18$$

Example : Calculate the molecular masses of the following.

(i) Ammonia (NH_3)

(ii) Carbon dioxide (CO_2)

Solution : $NH_3 = 14 + (3 \times 1) = 17$

$CO_2 = 12 + (16 \times 2) = 44$

Relative molecular mass is defined as the mass of one molecule compared to the mass of an atom of carbon —12, which is assigned a value of 12 000 a m.u.

Table 1 6

Element	Symbol	Atomic mass
Aluminium	Al	27.0
Calcium	Ca	40.1
Carbon	C	12.0
Chlorine	Cl	35.5
Copper	Cu	63.5
Hydrogen	H	1.0
Magnesium	Mg	24.3
Nitrogen	N	14.0
Oxygen	O	16.0
Potassium	K	39.
Silver	Ag	108
Sodium	Na	23.0
Sulphur	S	32.1
Zinc	Zn	65.4

Questions

1. What do you understand by a. m. u. ?

2. Calculate the molecular masses of (I) KCl,
   (II) Al_2O_3 , (III) H_2S , (IV) H_2SO_4

3. What is the difference between absolute mass and relative mass.

1.3 Chemical Equations

Consider the following reaction. Zinc reacts with sulphuric acid, zinc sulphate and hydrogen gas are formed. This reaction can be represented by a shorthand notation with the help of symbols and formulae of the various substances involved in the reaction as follows :

Zinc + Sulphuric acid → Zinc sulphate + Hydrogen

$Zn + H_2SO_4 \rightarrow ZnSo_4 + H_2$

This shorthand notation of a chemical reaction is known as chemical equation.

1.31 Writing of a Chemical Equation

The chemical equation for a reaction is written with the help of following points,

(i) The formulae or symbols of the reacting substances (reactants) are written on the left hand side with a plus (+) sign between them.

(ii) The formulae or symbols of substances formed (products) are written on the right hand side with a plus (+) sign between them.

(iii) An arrow (→) is put between the reactants and products pointing towards the products.

The equation thus obtained is known as a skeleton equation

1.32 Balancing a Chemical Equation

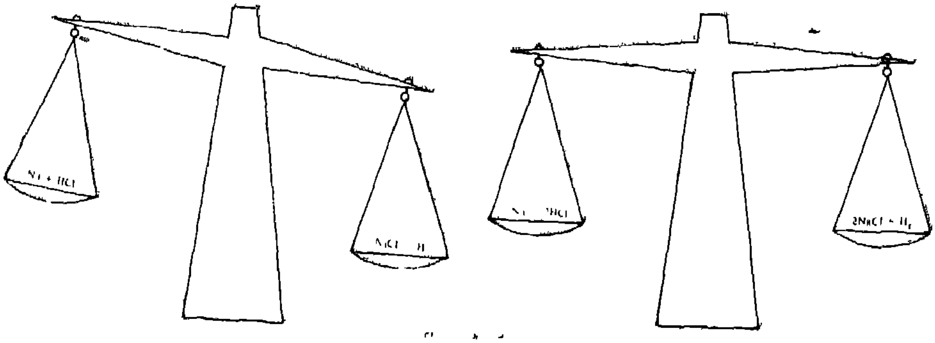


Fig 1.3 Balancing

Consider the following two equations :

$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$ . ...(i)

$Na + HCl \rightarrow NaCl + H_2$ .... (ii)

Equation (i) has equal number of atoms of different elements on left and right hand sides In equation (ii) there are equal number of sodium and chlorine atoms on both sides. But it has two hydrogen atoms on right and only one on left handside. Equation (i) is known as a balanced chemical equation while (ii) is an unbalanced equation From equation (ii), it appears that during the reaction, one H atom has increased resulting in the creation of mass. This is not so in real practice as no matter is created or destroyed during a chemical reaction (law of conservation of mass). Thus the number of atoms of each element must be the same on both sides in any chemical equation. To make the number of atoms of all elements equal on either side of the arrow in any equation is known as balancing of chemical equation.

There are two methods for balancing the chemical equations. These are

(i) Hit and trial method

(ii) Partial equation method.

(i) Hit and Trial Method

In this method the skeleton equation is first written The number of different elements are made equal on both sides of the arrow by placing the appropriate numerals before the formulae of reactants and products. Let us consider the skeleton equation for the reaction of water with sodium

$Na + H_2O \rightarrow NaOH + H_2$

In this equation the number of sodium and oxygen atoms are same on both sides of the equation while the numbers of hydrogen atoms are two on left and three on right. Hydrogen can be balanced if we put a coefficient 2 before H_2O and 2 before Na OH. In this way the number of oxygen atoms on the left and right side will be two. To balance sodium atom, put a coefficient 2 before NaOH in left hand side. So the balanced equation will be

$2 Na + 2H_2O \rightarrow 2NaOH + H_2$.

Example : Balance the equation

$CO_2 + Mg \rightarrow MgO + C$

(ii) Since the atoms of carbon and magnesium are balanced, to balance the oxygen atom put a coefficient 2 before MgO.

(iii) $CO_2 + Mg \rightarrow 2\ MgO + C$

In this way carbon and oxygen atoms have been balanced but not magnesium atoms. To balance the magnesium atom let us put a coefficient 2 before Mg on the left hand side and the equation becomes

$CO_2 + 2Mg \rightarrow 2MgO + C$

This is a balanced chemical equation in which each element is balanced.

Question

Balance the following chemical equations.

(i) $Fe + O_2 \rightarrow Fe_2O_3$

(ii) $Al_2(SO_4)_3 + NaOH \rightarrow Al(OH)_3 + Na_2SO_4$

(iii) $H_2 + O_2 \rightarrow H_2O$

(iv) $Mg + N_2 \rightarrow Mg_3N_2$

(v) $CaCO_3 + HCl \rightarrow CaCl_2 + H_2O + CO_2$

(ii) **Partial Equation Method** : This method is applied to equations which are difficult to balance by the hit and trial method. Such equations involve a greater number of substances either in the reactants or the products side. For example, the equation.

$K_2Cr_2O_7 + H_2SO_4 + SO_2 \rightarrow K_2SO_4 + Cr_2(SO_4)_3 + H_2O$

is difficult to balance by hit and trial method. It can be easily balanced by partial equation method as follows :

The overall reaction is first split into two steps. The equation for each step of the reaction is balanced by hit and trial method. These are the partial equations. The partial equations are then added. The common substances appearing on the reactants side in one equation are cancelled with the substances appearing on the products side. If needed the partially balanced equations are multiplied with suitable numerals so as to exactly cancel out the common elements. The above equation can be balanced by writing the following two partial equations and adding them together.

$$\begin{array}{ll} K_2Cr_2O_7 + 4H_2SO_4 \rightarrow K_2SO_4 + Cr_2(SO_4)_3 + 4H_2O + 3O & \text{(i)} \\ (H_2S + O \rightarrow H_2O + S) \times 3 & \text{(ii)} \\ \hline K_2Cr_2O_7 + 4H_2SO_4 + 3H_2S \rightarrow K_2SO_4 + Cr_2(SO_4)_3 + 7H_2O + 3S & \end{array}$$

Equation (ii) is multiplied by the numeral 3 so as to cancel the product O which does not appear in the final equation.

Example—2 For balancing

$$Zn + HNO_3 \rightarrow Zn\,(NO_3)_2 + N_2O + H_2O$$

it is split into the following two partial equations :

$$Zn + HNO_3 \rightarrow Zn(NO_3)_2 + H \qquad \text{(i)}$$

$$HNO_3 + H \rightarrow N\,O + H\,O \qquad \text{(ii)}$$

The two equations (i) and (ii) are balanced by Hit and Trial method.

$$Zn + 2HNO_3 = Zn\,(NO_3)_2 + 2H \qquad \text{(iii)}$$

$$2HNO_3 + 8H = N_2O + 5H_2O \qquad \text{(iv)}$$

Since H is an unstable species and does not appear in the final equation, it is cancelled out in equation (iii) with that in equation (iv). For this, equation (iii) is multiplied with 4 as there are 8 H in (iv) and only 2H in equation (iii). The two equations are then added to get a final equation.

$$\begin{array}{l} (Zn + 2HNO_3 \rightarrow Zn(NO_3)_2 + 2H) \quad \times 4 \\ (2HNO_3 + 8H \rightarrow N_2O + 5H_2O) \\ \hline 4Zn + 10HNO_3 \rightarrow 4Zn(NO_3)_2 + N_2O + 5H_2O \end{array}$$

Making Chemical Equations More Informative

A chemical equation can be made more meaningful by providing (i) the states of the reactants and the products and (ii) the reaction conditions.

The information about the states of substances is provided by using the symbols (s), (l), (g) and (aq) for a solid, liquid, gas and a solution in water respectively. The gas is also sometimes shown by a vertical arrow (↑) pointing upwards. These symbols are written after the formulae of substances involved

$$2Na(s) + 2H_2O(l) \rightarrow 2NaOH\ (aq) + H_2(g)$$

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

The reaction conditions i.e. the temperature, pressure or catalyst of the reaction are indicated above or below the arrow in chemical equation.

For example

$$N_2(g) + 3H_2(g) \xrightarrow[Fe+Mo]{450°C,\ 200-900\ atm.} 2NH_3(g)$$

Questions

1. What informations can be derived from the following equation ;

$$2H_2(g) + O_2(g) \rightarrow 2H_2O\ (l)$$

2. What is Law of Conservation of Mass ?

3. Why do we need to balance a chemical equation ?

4. Balance the following chemical equations ;

(i) $N_2 + O_2 \rightarrow NO$

(ii) $N_2 + H_2 \rightarrow NH_3$

(iii) $C_6H_6 + O_2 \rightarrow CO_2 + H_2O$

(iv) $Fe + O_2 \rightarrow Fe_2O_3$

(v) $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$

1.34 Calculations based on Chemical Equations

A chemical equation provides qualitative as well as quantitative information about the chemical reaction. They give us the information needed for calculating the masses or volumes of the substances consumed or produced in a chemical reaction. Some of the numerical problems based on chemical equations are illustrated here.

Example—1

The reaction between hydrogen and chlorine takes place according to the reaction,

$H_2+Cl_2 \rightarrow 2HCl$.

(a) How many molecules of HCl can be formed using one molecule of hydrogen ?

(b) How many molecules of HCl can be formed using four molecules of chlorine ?

(c) How many molecules of chlorine are required to produce 16 molecules of hydrogen chloride ?

Solution

(a) From the equation given above, we can say that

1 molecule of H_2 + 1 molecule of Cl_2 = 2 molecules of hydrogen chloride

1 molecule of $H_2 \equiv 2$ molecules of HCl

Therefore, for each molecule of H_2, 2 molecules of HCl are formed.

(b) From the equation, we can say that

1 molecule of $Cl_2 \equiv 2$ molecules of HCl. It means that one molecule of chlorine can produce 2 molecules of HCl. Therefore, from 4 molecules of Cl_2, 8 molecules of HCl will be formed

$4\ Cl_2 \equiv 8\ HCl$

(c) From the equation, we can say that

2 molecules of HCl can be prepared from 1 molecule of Cl_2. Therefore, 16 molecules of HCl will be produced by 8 molecules of Cl_2.

Therefore $8\ Cl_2 \equiv 16\ HCl$

Example—2

3 g. of a substance 'A' combines with 4 g of substance 'B' to give 5 g. of

substance 'C' and some substance 'D'. How many grams of D will be formed ?

Solution : The reaction is,

$$A + B \rightarrow C + D$$

From the law of conservation of mass; we can say that the total mass before and after the reaction should be the same. Therefore in the above equation :

weight of A + weight of B → weight of C + weight of D

In our problem

Weight of $A = 3$ g

Weight of $B = 4$ g

Weight of $C = 5$ g.

Weight of D = Unknown

Therefore $3+4=5+W$

$W=(3+4)-5$

$W=7-5$

$W=2$ g.

The weight of substance 'D' formed $=2$g.

Example—3

Copper wire reacts with silver nitrate solution to give silver metal and a solution of copper nitrate, $Cu(NO_3)_2$.

(a) Write a balanced chemical equation for the reaction.

(b) How many grams of metallic silver would be produced if 2.37 g. copper completely reacts with silver nitrate ?

Solution :

(a) The skeleton equation for the reaction is
copper + silver nitrate → silver + copper nitrate
$Cu + AgNO_3 \rightarrow Ag + Cu(NO_3)_2$

This equation shows that nitrogen and oxygen can be balanced by placing a coefficient of 2 before $AgNO_3$. Ag atoms can be balanced by putting coefficient of 2 before Ag. Then, the balanced equation is,

$$Cu + 2\ AgNO_3 \rightarrow 2\ Ag + Cu\ (NO_3)_2$$

(Atomic mass of Cu is 63.5)

(Atomic mass of Ag is 107.9)

(b) From the above balanced equation, we see that

One atom of Cu produces 2 atoms of Ag

63.5g Cu produces $(2 \times 107.9g) = 215.8$ grms Ag.

Thus,

$$1\text{ g. of Cu produces} = \frac{215\ 8}{63.5}\text{g. silver}$$

$$2.37\text{ gm of Cu produces} = \frac{215.8}{63.8} \times 2.37 = 8.05\text{g. of Ag.}$$

IV. ASSIGNMENT

1. Classify each of the following as an element, compound or mixture :
   (a) air, (b) water, (c) carbon dioxide, (d) tea (e) common salt, (f) campa cola, (g) oxygen, (h) silver, (i) milk, (g) gold, (k) paper and (l) blood. M

2. Briefly give reason why you have put the above substances under the three different groups.

3. Calculate the valency of each element as indicated in the following formulae of compounds.

   (a) H_2O, (b) N_2O_5, (c) CH_4, (d) $CaCl_2$, (e) NH_3, (f) NaCl, (g) H_2S,

4. Write the formulae of following compounds

   (a) Potassium bicarbonate

   (b) Silver nitrate

   (c) Magnesium phosphate

   (d) Aluminium bromide

   (e) Barium sulphate.

5. (a) Fill up the blanks in the following sentences with the appropriate words.

   (i) The smallest particle of a substance, existing in the free state and showing specific properties is termed as . .

   (ii) The mass of one molecule of an element or a compound compared with mass of an atom of carbon—12 taken as 12.000 a.m.u. is known as . .. .

   (iii) The atomic mass of an element expressed in grams is known as. .. . .

   (b) The following reactions are given to represent the production of carbon dioxide.

   (i) $CaCO_3 \longrightarrow CaO + CO_2$

   (ii) $MgCO_3 + 2HCl \longrightarrow MgCl_2 + H_2O + CO_2$

   (iii) $2NaHCO_3 \longrightarrow Na_2CO_3 + H_2O + CO_2 +$

Now answer the following questions :

(a) The collection of symbols and formulae intended to represent a chemical change is called... ... .

(b) In all cases it is found that carbon dioxide produced in different ways, always contain 12 grms of Carbon and 32 grms of Oxygen. State the law which governs the above observations.

(c) Mention the information conveyed by reaction (i) represented above regarding the state of reactants and products.

(d) How many grams of calcium carbonate are needed to get

(i) 112 gms of calcium oxide, and

(ii) 22 gms of carbon dioxide separately.

6. Balance the following equations :

(i) $Na+H_2O \rightarrow NaCl+H_2$

(ii) $N_2+H_2 \rightarrow NH_3$

(iii) $CH_4+O_2 \rightarrow CO_2+H_2O$

(iv) $KClO_3 \rightarrow KCl+O_2$

(v) $Cu+HNO_3 \rightarrow Cu(NO_3)_2+NO_2+H_2O$

(vi) $H_2+Cl_2 \rightarrow HCl$

7. Methane burns in oxygen to form carbon dioxide and water. Calculate the mass of oxygen required to completely burn 1.6 gram of methane.

8. Write the maximum information which can be derived from the following equation :

$$2\,KClO_3(s) \xrightarrow[MnO_2]{Heat} 2KCl(s)+3O_2(g)$$

7. SELF ASSESSMENT

. Mohan carried out the separation of constituents of a mixture of iron filings, sand and salt He first brought a powerful magnet near the sample when iron filings stuck to the magnet. The sample containing sand and salt was treated with water and filtered. He got residue of sand. The salt was obtained in the filtrate. The solution was subjected to evaporation in order to get salt. Now answer the following questions.

a) Name various mixtures got by Mohan during different stages of operation.

b) Why are they termed as mixtures ?

c) Name various mixtures which are homogeneous and which are heterogeneous and justify your classification.

d) Name elements in the above initial mixture.

e) Identify the compounds in the above initial sample.

f On the basis of the above findings, define mixture, element and compound.

2 The formula of water, H_2O, indicates that the valency of O is 2 Now calculate with argument different valencies of N in N_2O, NO, NO_2, N_2O_3 and N_2O_5.

3 Burning magensium wire is introduced into a jar of carbon dioxide (CO_2). It is found that magnesium wire continues to burn producing carbon particles and Oxide of magnesium (MgO) along with evolution of heat. Now answer the following questions :

a) Write balanced chemical equation for the above change.

b) The atomic masses of elements involved are Mg=24, O=16, C=12. What do you understand by atomic mass, explain. Name unit of atomic mass and define it.

c) Calculate molecular mass of the compound formed.

d) What informations are being conveyed by the above chemical equation pertaining to reactants and resultants ?

e) State the law which governs the relationship between mass of substances taking part in the above reaction.

f) Will the chemical composition of oxide of magnesium produced above be different from oxide of magnesium formed, as a result of burning magnesium in oxygen ? Justify your response.

g) How many grams of magnesium oxide and carbon will be produced by burning 100 grams of magnesium in a jar of carbon dioxide ?

UNIT—I

TEACHER'S GUIDE

NATURE AND COMPOSITION OF MATTER-I

This unit consists of a number of concepts which form the backbone of chemistry. The clarity of these concepts is a must to understand the later portions of the subject. Following topics may be discussed in the class.

Law of constant composition, valency, atomic mass unit and balancing of chemical equations.

Law of constant composition

Demonstration - I

Electrolysis of samples of water from different sources may be carried out for a fixed time using the improvised apparatus shown below :

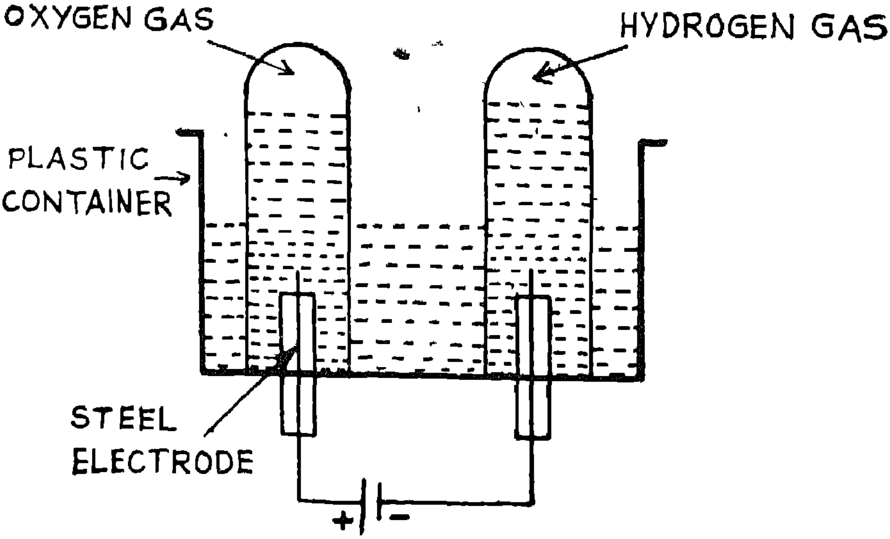


Fig. 1.1

Collect hydrogen and oxygen gas obtained from each sample. Multiply the volumes with densities of gases to get their masses. Find the ratio of the masses of hydrogen and oxygen for each sample.

Sample No.	Volume of H_2	Volume of O_2	Mass of H_2	Mass of O_2	Ratio H_2/O_2
1.					
2.					
3.					

Demonstration—2

Preparation of zinc chloride

Weigh about 2 grams of zinc and place it in a test tube. Add 10 c c of hydrochloric acid to it. To ensure that the reaction is complete, allow the mixture of zinc and acid to stand overnight. Pour the liquid from the test tube into an evaporating dish already weighed. If there is still zinc left over, pour the solution so that the solid stays in the test tube. Wash the test tube and any of unreacted zinc with 5 c.c. of water. Dry the left-over zinc and weigh it. Find the mass of the metal that reacted with hydrochloric acid. Evaporate the solution in evaporating dish by heating. Weigh the dish and its contents. Find the ratio of the mass of zinc reacted to the mass of zinc chloride formed. Compare the results obtained by different groups in the class ? What law in chemistry does the results illustrate ? Did an excess of zinc or hydrochloric acid affect the results of different groups ?

Demonstration—3

Law of Conservation of Mass

Pour lead nitrate solution into a small beaker until it is about 1/3rd full. Now pour nearly the same volume of potassium chromate into another beaker of the same size. Find the total mass of the beakers and solutions Now pour one solution into the solution of another beaker, Find the total mass of both beakers, again. Did the total mass change as a result of mixing and chemical reaction ?

$$Pb\ (NO_3)_2+K_2CrO_4 \rightarrow PbCrO_4+2KNO_3$$

UNIT–I

Assessment–I

1. Fill up the appropriate words in blanks in following statements :

   (a) A compound composed of two elements was prepared by two different methods. The ratio of masses of elements present in the two samples will be ....

   (b) A substance which consists of only one type of atoms and can not be changed into anything simpler than itself is called ....

   (c) One atomic mass unit is equal to .... of mass of one atom ....

   (d) A collection of symbols and formulae intended to represent a chemical change is called a ....

   (e) The mass of reactants and products during a chemical change remains ....

   (f) Substances composed of two or more elements united chemically in a definite proportion by mass are called ....

   (g) When two or more substances are mixed physically in any ratio, the resulting product is known as ....

2. List the following substances under element, mixture and compound : salt, water, campa cola, iron, hydrogen gas, gold, H_2S, SO_2, ammonium chloride

3 Valencies and symbols of following elements/radicals are given. Write the formulae of barium sulphate, aluminium sulphate, barium chloride and aluminium chloride.

Name	*Symbol*	*Valency*
Barium	Ba	2
Sulphate	SO_4^{2-}	2
Chloride	Cl^-	1
Aluminium	Al	3

4. Calculate the amount of magnesium oxide formed as a result of burning 96 grams of magnesium in an atmosphere of carbon dioxide. Atomic masses of Mg = 24, O = 16 and C = 12

5. Balance the following equations :

(a) $Al + O_2 \rightarrow Al_2 O_3$

(b) $H_2S + SO_2 \rightarrow S + H_2O$

(c) $C_2H_4 + O_2 \rightarrow CO_2 + H_2O$

Assessment-II

1. (a) Valencies and symbols of following elements are given. Write formula of iron (II) phosphate, iron (II) sulphate and iron (III) sulphate.

Name	*Symbol*	*Valency*
Iron (II)	Fe^{2+}	2
Iron (III)	Fe^{3+}	3
Phosphate	PO_4^{3-}	3
Sulphate	SO_4^{2-}	2

(b) Write the chemical equations for the following reactions :

(i) reaction of sodium with chlorine to give sodium chloride.

(ii) reaction of aqueous barium chloride with sodium sulphate to give barium sulphate and sodium chloride.

(iii) combustion of CH_4 in air to give CO_2 and H_2O.

2. Fill in the appropriate words in blanks in following sentences.

(a) One atomic mass unit is equal to.. mass of one atom ....

(b) A collection of symbols and formulae intended to represent a chemical change is called a ....

3. (a) Will chemical composition of sodium chloride obtained from different sources differ ? Justify your response.

(b) Identify each of the following substances as element, mixture and compound.

(i) copper, (ii) iron, (iii) salt, (iv) aluminium chloride, (v) brass, (vi) water.

4. (a) Define the term valency,

Formula of copper sulphate is Cu SO_4 Calculate valencies of its constituent parts.

(b) How many grams of sodium and chlorine are required to prepare 234 grams of sodium chloride ? (At. masses of Na=23, Cl=35.5)

5. List three informations, conveyed by chemical equations.

—o—

Assessment—III

1. Formulae of magnesium nitride and aluminium oxide are Mg_3N_2 and Al_2O_3 respectively. Write formula of aluminium nitride.

2. (a) On reacting calcium carbonate with hydrochloric acid, calcium chloride, water and carbon dioxide are obtained. Express the reaction in the form of a chemical equation.

   (b) How many grams of calcium carbonate and hydrochloric acid are required to produce 22 grams of carbon dioxide (Ca = 40, C = 12, 0 = 16, H = 1 and Cl = 35.5)

3. (a) State the law which governs the relationship between masses of reacting substances and products. Give examples.

   (b) State three informations that are conveyed by a chemical equation $2Mg(s) + O_2(g) \longrightarrow 2MgO(s)$

4. (a) There are various ways of preparing carbon dioxide. Does its chemical composition differ in each case ? Justify your response.

   (b) Classify blood, carbon dioxide, copper sulphate, gold, brass, iron, air, water, H_2 and H_2S gases into element, compound and mixture.

5. Fill appropriate words in blanks in following statements.

   (a) Symbolic representation of a molecule of an element or compound is termed as . ...

   (b) Where two or more substances are mixed physically in any ratio, the resulting product is known as............ ..

   (c) The molecular mass of a compound is the sum of the .. ..of the elements present in it.

   (d) In a chemical reaction, the mass of the reactants is ....to the mass of the products.

UNIT--I

Assessment—IV

1. (a) Classify milk, hydrogen, nitrogen, magnesium nitride, water, H_2S and Cl_2 into element, compound and mixture.

   (b) There are various sources of obtaining water. Does its chemical composition depend upon the source ? Justify your response.

2. (a) Mohan reacted 100 grams of reactants. After all the reactants converted into products, 99 grams of resulting products were obtained Did Mohan commit any mistake ? Explain

3. (a) On heating magnesium carbonate, magnesium oxide and carbon dioxide are produced. Write a chemical equation for the above reaction.

   (b) How many grams of magnesium carbonate is needed to produce 80 grams of magnesium oxide ? (Mg=24 3, C=12, 0=16).

4. Write formula of iron (III) sulphate with the help of formula of iron (III) chloride ($FeCl_3$) and sulphuric acid ($H_2\ SO_4$).

5. Write the chemical equations for the following reactions;

   (i) Combustion of $C_2\ H_4$ in presence of air to give CO_2 and H_2O.

   (ii) heating aluminium in air to give Al_2O_3.

   (iii) reaction of H_2S and SO_2 to form S and H_2O.

Assessment - V

1. Explain the terms (a) valency and (b) compound with examples.

2 The formulae of phoshoric acid (H_3PO_4), ammonium chloride (NH_4Cl) and hydrochloric acid (HCl) are given in brackets with Them. Write the formula of ammonium phosphate.

3 (a) On reacting nitrogen and hydrogen, ammonia is produced. Represent the reaction in the form of chemical equation.

(b) Calculate the amounts of nitrogen and hydrogen needed to produce 3.4 grams of ammonia.

4. (a) State three informations given by the chemical equation

$$2H_2S\ (g) + SO_2\ (g) \rightarrow 3\ S\ (s) + 2H_2O\ (l)$$

(b) Illustrate and explain with two suitable examples the law of constant proportions.

5. (a) Which law is used to balance chemical equations ? Explain the law under question.

(b) Classify stainless steel, barium sulphate, nitrogen dioxide, sulphur, water, salt and H_2S into element mixture, and compound.

Unit - 2

Nature and Composition of Matter-II

I. Introduction

In the previous unit, we studied that matter can be classified into three categories namely, elements, mixtures and compounds. These three categories of matter can exist in the form of solid, liquid or gas Hence matter can also be classified into solid, liquid and gas. These different forms are known as the different states of matter. We observe in daily life – solids (wood, metal, ice), liquids (water, milk, kerosene petrol) and gases (steam, air). Water is an example whose three states (solid, liquid and gas) are very common. One form of water can be changed into another form by changing the temperature and pressure Water which exists as liquid at ordinary temperature can be changed into ice (solid) by cooling it to 0°C, and into steam by heating to 100°C. Similarly the states of all the other substances can be converted into one another by changing the temperature and pressure. This behaviour of states of matter is a very interesting phenomenon. In this unit, we shall study about the three states of matter and the effect of changing any one or more factors such as pressure, volume and temperature on the remaining factors. This study will help us at a latter stage to understand the interesting behaviour of conversion of one state of matter into another.

II. Objectives

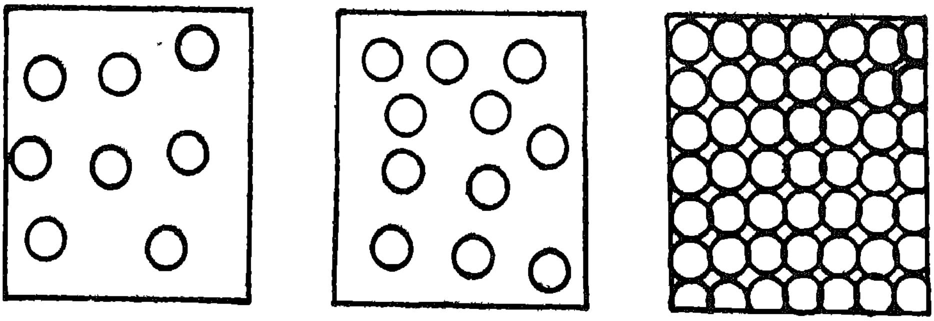
After completing this unit, you should be able to;

1. Explain the three states of matter on the basis of the distances between constituting molecules.
2. Express the concentration of a solution in terms of units based on number of molecules of solute.
3. Explain laws pertaining to behaviour of gases.
4. Derive the relationships between pressure, volume and temperature of a gas.
5. Solve problems based on gas laws.

2.1 States of Matter

Irrespective of its physical states, the matter consists of a large number of very small particles known as molecules. These molecules are held together by certain forces known as molecular forces. The molecules of a gas are in constant motion. Based on this molecular model, matter can be classified according to its physical states i.e solid, liquid and gas

A solid has a definite shape and volume A liquid has a definite volume but no fixed shape. A gas has no fixed volume or shape. These different characteristics of three states of matter depend upon the relative closeness of molecules that make up the substance. In gases, molecules are farthest apart from each other. In liquids the molecules are much closer together while in solids the molecules are closest to each other. The arrangement of molecules in gas, liquid and solid can be described with the following diagram.



Gaseous State

Liquid State

Solid State

Fig. 2.1

Most of the substances can be changed from one state of matter to another by heating or cooling the substances. Heating and cooling results in increasing and decreasing distances between the molecules respectively, the pressure being constant.

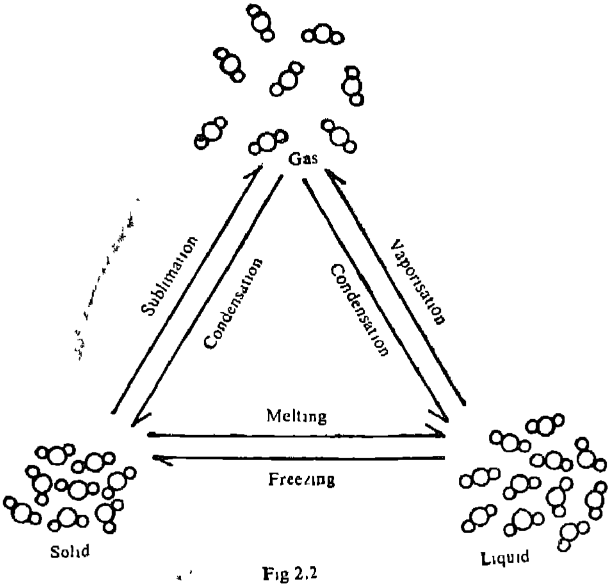


Fig. 2.2

2 2 Quantitative Measurements

Of the three states of matter, gaseous state has been discussed in detail in this unit. The detailed discussion of gaseous state involves the use of quantitative measurements. Following quantitative measurements are used frequently in the study of chemistry.

2 2 1 Gram Molecular Mass

The molecular mass of any substance expressed in grams is known as its gram molecular mass. For example, molecular mass of hydrogen (H_2) is 2, its gram molecular mass is 2 grams.

2.2.2 Mole

You have studied the law of constant proportion in unit—1. According to this law, a chemical compound always contains the same elements in the same ratio. It means, in the reaction

$$Ca + 2Cl \rightarrow CaCl_2$$

One calcium atom unites with two chlorine atoms to form one $CaCl_2$ unit. Similarly 100 Ca atoms will combine with 200 Cl atoms to produce 100 $CaCl_2$ units. Similarly if one H^+ combines with one OH^- to form one H_2O unit,

$$H^+ + OH^- \longrightarrow H_2O$$

50,000 H^+ will react with exactly 50,000 OH^- to make 50,000 H_2O units.

Suppose we are to prepare carbon dioxide by burning carbon in oxygen. The chemical equation of the reaction is

$$C + O_2 \longrightarrow CO_2$$

This equation simply tells us that one CO_2 molecule is obtained from one carbon atom. But if we want to prepare 2 grams of CO_2, how many carbon atoms do we need ? All that we can say at this stage is that if X number of CO_2 molecules weigh 2 grams, X number of carbon atoms would be required.

Since an atom or a molecule is a very small entity, a very-very large number of carbon atoms/carbon dioxide molecules make up 2 grams. The counting of such a large number of atoms or molecules is not possible practically. But weighing any collection of atoms or molecules is easy. The wheat or rice, for example, is bought and sold by weight and not by their number. Therefore a relationship is required between the mass of carbon or any other element to the number of atoms in that mass.

We know that each calcium atom (atomic mass = 40) is 40 times as heavy as each hydrogen atom (atomic mass = 1)

$$\frac{40}{1} = \frac{\text{Mass of 1 calcium atom}}{\text{Mass of 1 hydrogen atom}}$$

$$= \frac{\text{Mass of 100 calcium atoms}}{\text{Mass of 100 hydrogen atoms}}$$

$$= \frac{\text{Mass of n calcium atoms}}{\text{Mass of n hydrogen atoms}}$$

$$= \frac{\text{Mass of N calcium atoms}}{\text{Mass of N hydrogen atoms}}$$

The above equation shows that ratio 40/1 remains the same irrespective of number of Ca and H atoms. In this process, of increasing the number of atoms, a stage reaches when the total number of hydrogen atoms weigh equal to gram atomic mass of hydrogen i e. 1 g. The number of atoms or molecules which weigh equal to their gram atomic mass/gram molecular mass is represented by N and is known as Avogadro's number.

In case of sodium (atomic mass 23), the gram atomic mass of N atoms of sodium is 23 grams.

Therefore

$$\frac{\text{Mass of N atoms of sodium}}{\text{Mass of N atoms of hydrogen}} = \frac{23}{1}$$

$$\text{or } \frac{\text{Mass of N atoms of any element}}{\text{Mass of N atoms of hydrogen}} = \frac{\text{Atomic mass of element}}{\text{Atomic mass of hydrogen}}$$

The number N, known as Avogadro's number has been numerically found to be 6.023×10^{23}.

Thus if a dozen is the name of 12 things, a score for 20 things and a gross for the collection of 144 things, a mole is a collection of 6.023×10^{23} things. A mole of any chemical species will have a mass equal to the formula mass of that species whether it is an atom, a molecule or ion. For example, 1 mole of O_2 = N molecules of $O_2 = 6.023 \times 10^{23}$ molecules of O_2 = 32 grams of O_2.

1 mole of NaCl = N molecules of NaCl = 6.023×10^{23} molecules of NaCl = molecular Mass of NaCl = 23 + 35.5 = 58.5 grams of NaCl.

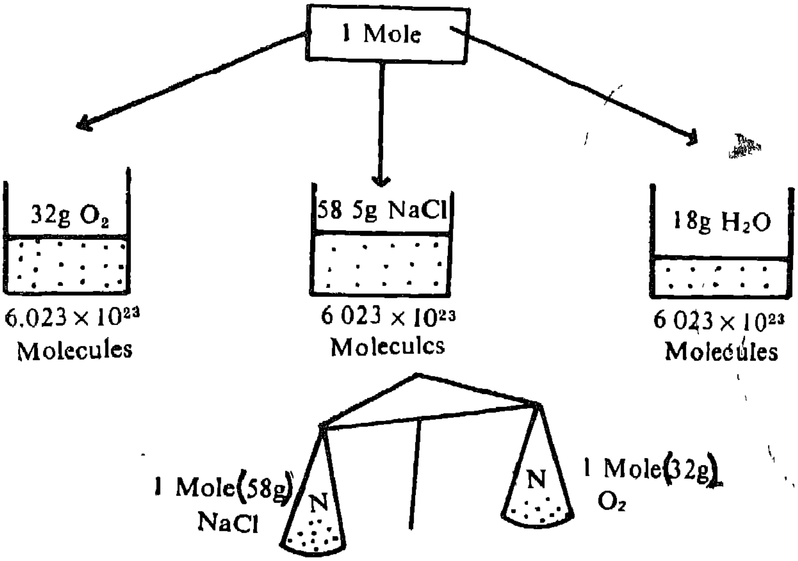

1 Mole
32g O_2
6.023×10^{23} Molecules
58 5g NaCl
$6\ 023 \times 10^{23}$ Moleculcs
18g H_2O
$6\ 023 \times 10^{23}$ Molecules
1 Mole(58g) NaCl
N
N
1 Mole(32g) O_2

Fig 2 3

The number of molecules may be the same but their masses may vary.

Meaning of 6.023×10^{23}

$$100 = 10 \times 10 = 10^2$$

$$1000 = 10 \times 10 \times 10 = 10^3$$

$$1000000 = 10 \times 10 \times 10 \times 10 \times 10 \times 10 = 10^6$$

Thus 1 with 23 zeros $= 10^{23}$

2.2.3 The Mole in Chemical Reactions

Mole is a very imprortant chemist's unit. Through this unit, we can know how many atoms or molecules of reactants participate in the reaction Also we can know how many atoms or molecules of products are formed. Consider the following equation ;

$$C + O_2 \longrightarrow CO_2$$

According to this equation, one atom of carbon combines with one molecule of oxygen to form one molecule of carbon dioxide.

The reaction could occur N times.

or $\quad N\,C + N\,O_2 \rightarrow N\,CO_2$

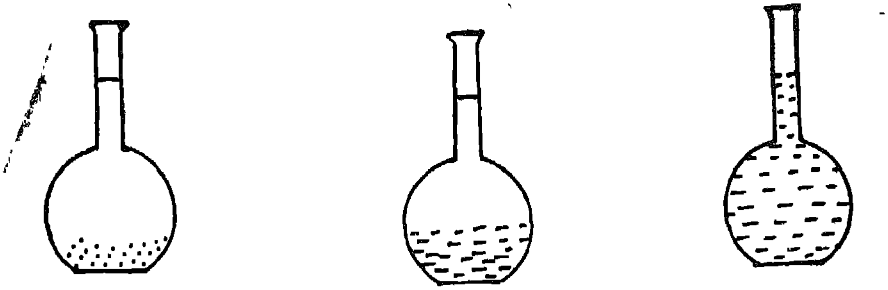
1 mole C + 1 mole O_2 → 1 mole CO_2

12 g 32 g 44 g (gram molecular mass)

2.2.4 Molar Solution

In Chemistry, the concentration of a solution is generally expressed in units of moles. A solution containing one mole of solute per litre of solution is called a one molar solution. A one molar solution is one which contains one mole or one gram molecular mass solute per litre of solution.

To prepare one molar solution, we first find the gram molecular mass of the solute by adding the atomic masses of different atoms making up the solute molecule. This amount of solute is weighed and dissolved in less than one litre of solvent. When the solute is dissolved, we add more solvent to it till the total volume of the solution becomes one litre (Fig. 2.4).



58 5g or 1 Mole of NaCl in a 1L Volumetric Flask

Water added to dessolve NaCl

More water added to make the Volume 1L

Fig 2 4 Preparing a 1M Solution of NaCl

Example

Preparation of 500 c.c. of 0.5 M NaCl solution.

(i) First find the gram molecular mass of sodium chloride

$$NaCl = 23 \text{ g} + 35.5 \text{ g} = 58.5 \text{ g}$$

(ii) To prepare 1000 c.c. of solution, mass of NaCl required =58.5 g.

(iii) To prepare 0.5 molar solution, mass of NaCl required

$$= 58.5 \times 0\ 5 = 29.25 \text{ g.}$$

To prepare 500 ml of 0.5 molar solution, mass of NaCl required

$$= \frac{29.25 \times 500}{1000} = 14.625 \text{ g}$$

A solution containing 14.625 grams of NaCl in 500 c.c. solution is a 0 5 molar solution. The most common way of expressing the concentration of a solution is by its molarity 'M'. Molarity is the number of moles of solute dissolved in one litre of the solution.

Mathematically $M = \frac{n}{v}$

Where M = molarity, n = number of moles of solute dissolved

v = volume of solution in litres.

The same volume of one molar solutions of all substances will have the same number of molecules of solute. For example 100 c.c. of 1 molar solution of ethyl alcohol, sugar, glucose and urea will have the same number of solute molecules in it.

2.2.5 S.T P

S.T.P. stands for standard temperature pressure At S.T.P, any substance has a temperature 273 K and pressure of one atmosphere i.e. 76 cm of Hg.

2.2 6 Gram Molecular Volume

Gram molecular volume is frequently used while dealing with gases. The gram molecular volume of a gas is the volume of 1 mole of a gas and is also called molar volume. All gases have a molar volume of 22.4 litres at S.T.P. For example, one mole of hydrogen (molecular mass 2) has a gram molecular mass of 2 grams. Its molar volume at STP is 22.4 litres.

Questions

1. Define a molar solution. How is one molar solution prepared ?
2. A solution contains 5.8 grams of sodium chloride in 250 c.c of solution. What is the concentration of this solution ?
3. What do you mean by (i) S T.P. and (ii) molar volume of a gas ?
4. What is the relationship between mole and gram molecular mass ?
5. What is Avogadro's number ?
6. How many atoms of potassium are present in 3.91 g of potassium ? (At. mass of Potassium is 39.1).
7. How many molecules are present in gram molecular mass of a substance ?
8. Which has more particles in it ?
    - (i) 20 g of sodium chloride or 20 g of potassium.
    - (ii) 3 g of ammonia or 3 g of methane (CH_4).

2 3 Gaseous State of Matter

As you blow into a balloon again and again, it expands and becomes hard When you put air into a tyre—tube, it also expands and becomes hard. Apparently the air pushes on the inside of the balloon and tyre-tube, and stretches their elastic surfaces. These observations can be explained if we consider that air is made up of very small particles that are never still. These particles, known as molecules never come to a stand still. The molecules occupy whatever volume is available. For example if an agarbati is lighted in one corner of a room, soon its fragrent odour is recognised at the other corner.

The volume of a gas changes if the pressure and temperature of the gas are changed. There is a definite relationship between pressure (P), volume (V) and temperature (T) of a gas. In the following sections, we shall study about the relationships between P, V and T. These relationships are known as gas laws.

2.31 Pressure Exerted by a Gas

As the molecules of a gas are farther away from one another, they can be squeezed in a small volume as in the case of balloon or tyre-tube. And as is indicated by the inflated balloon and tyre-tube, the molecules exert pressure on the walls of the container when squeezed into a smaller volume. Let us first understand what pressure is and how a gas exerts pressure. Pressure is defined as the amount of force per unit area. If a box weighing 100 grams is placed as shown, 100 grams is spread over 4 cm^2 and the pressure is 25 grams per cm^2.

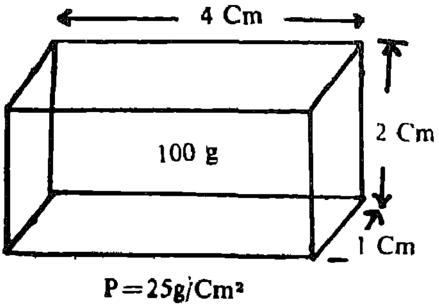


Fig. 2.5

In chemistry, the unit atmosphere is used as the unit of pressure. This is the amount of force exerted by earth's atmosphere at sea level on a unit area.

But the atmospheric pressure varies depending on the height above the earth's surface. At distances of about 80 miles above the surface of earth, the pressure of the air is less than one millionth of that at the surface. At the surface of earth, it exerts a maximum pressure or, as we say, atmospheric pressure. One atmospheric pressure is defined as the pressure exerted by a column of pure mercury exactly 760 millimetres high, measured at 0°C at sea level and at 45° latitude.

The gas exerts pressure due to the collision of its molecules with the walls of the container and with each other Each time a molecule collides, it imparts a small push to the wall. This can be visualized in terms of billiard balls moving on a table. When a billiard ball is set in motion and allowed to strike one side of the table, it rebounds and moves until it strikes another edge of the billiard table. It might still continue to move and strike the edges at different places. If more billiard balls on the table are set in motion, they would strike with the edges and with each other. The edges of the table are not of rubber as in case of balloon or tyre-tube. Otherwise when many balls strike the edges, they would stretch out like a balloon or tyre-tube. The increase in the number of moving billiard balls increase the number of collisions. Similarly the increase in the quantity of gas (number of molecules) in a given volume will increase the number of collisions of molecules on the walls of container. It would exert more pressure. Actually there is a definite relationship between the pressure and volume of a gas.

2.32 Pressure—Volume Relationship—Boyle's Law

If we take a container with a movable piston and put some weight over it, the piston will go down and compress the air in the container. The increase in the weight on the piston pushes it further down.

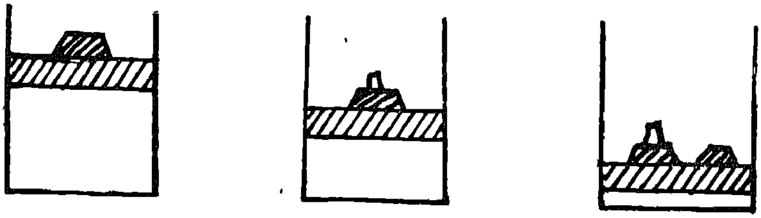


Fig 2.6

In other words. the volume of the gas decreases as the pressure increases.

If a graph between pressure and volume is plotted, a curve is obtained as shown.

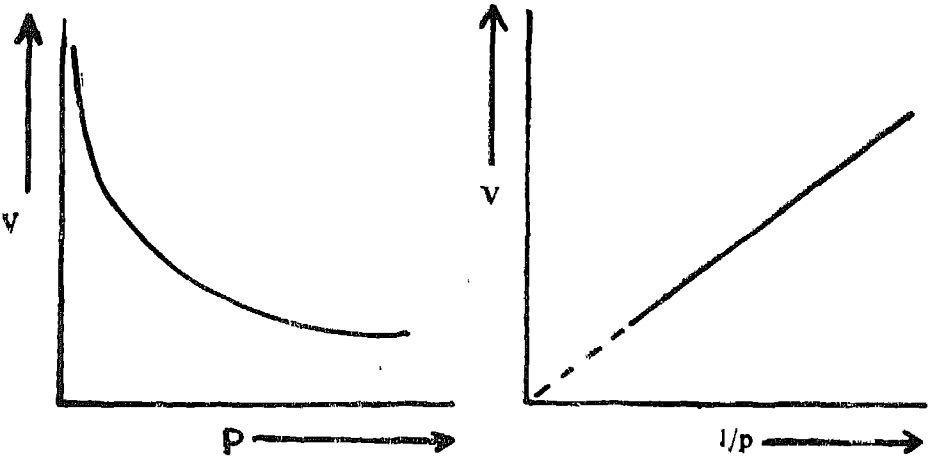


Fig. 2.7 : Variation of volume of a gas with pressure.

Robert Boyle, an Irish scientist found a relationship between pressure and volume of a gas. According to Boyle's law, the volume (V) of a given mass of a gas is inversely proportional to its pressure at a constant temperature.

$$P \alpha \frac{1}{V}$$

$$PV = \text{constant}$$

In other words, the product of pressure and volume of a gas is constant at a given temperature. Consider a given mass of a gas at pressure P_1 and volume V_1. According to Boyle's Law,

$$P_1V_1 = \text{constant} \quad \ldots \quad \ldots \quad \ldots \quad \text{(i)}$$

Keeping the temperature same, change the pressure to P_2. Let the volume V_1 become V_2. Then

$$P_2V_2 = \text{constant} \quad \ldots \quad \ldots \quad \ldots \quad \text{(ii)}$$

From equations (i) and (ii), we get

$$P_1V_1 = P_2V_2$$

Problem

In an experiment, 100 c.c. of oxygen gas at a pressure of 720 mm of mercury is changed to 800 mm pressure. Calculate the volume of the gas ?

Solution

$P_1 = 720$ mm $\qquad P_2 = 800$ mm

$V_1 = 100$ c.c. $\qquad V_2 = ?$

$P_1V_1 = P_2V_2$

$$V_2 = \frac{P_1V_1}{P_2} = \frac{720X100}{800} = 90\text{c c.}$$

Student Activity

Take a syringe and raise its piston to fill the syringe with air. Fit the nozzle of the syringe with a cork as shown in the figure. Put some weight on

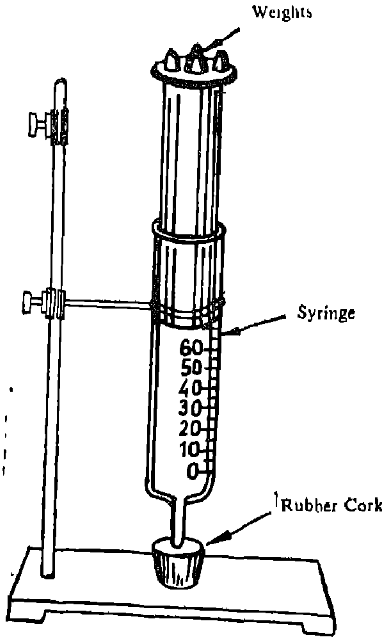


Fig 2 8

the piston which moves down. Note the level at which the piston stops. Increase the weight on the piston and again note its level. In this way, record four to five readings. Plot a graph between V and 1/P.

2 33 Temperature – Volume Relationship-Charles Law

The relationship between volume of a gas and its temperature was discovered by Jacques Charles in 1787. He kept the pressure of the gas constant and observed the changes in volume as the temperature was changed It was found that, at constant pressure the volume increased as the temperature increased.

A similar experiment performed in laboratory gave results as given in table 2.1

TABLE—2.1

Temperature in °C	*Volume in c.c.*
30°	303
20°	293
10°	283
0°	273
—100°	173
—200°	73

A study of the above data shows that for each degree change in temperature the volume of a given quantity of gas changes by $\frac{1}{273}$ of its volume at 0°C. This is known as Charles law.

Kelvin Scale

The temperature –273°C is called absolute zero It is 0° on Kelvin Scale of temperature. The temperature in celcius is converted into Kelvin by adding 273.

Kelvin temperature = Celcius temperature + 273

$K = {}^\circ C + 273$

The relationship between the Kelvin temperature of a gas and its volume is given by Charles Law. According to this law, the volume of a gas is directly proportional to its Kelvin temperature.

Mathematically $V \alpha T$

$$\frac{V}{T} = \text{constant}$$

$$\text{or } \frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Problem

During an experiment 100 c.c. of oxygen gas was collected at a temperature of 35°C and pressure of 760 mm. What would be the volume of gas at 0°C if the pressure remains the same ?

Solution ·

$T_1 = 273 + 25^\circ C = 298\ K$

$T_2 = 273 + 0^\circ C = 273\ K$

$V_1 = 100$ c.c.

$V_2 = ?$

Applying Charles Law,

$$\frac{V_2}{100} = \frac{273}{298}$$

$$V_2 = \frac{273 \times 100}{298} = 91.6 \text{ c c}$$

As the new temperature is lower than the starting temperature we would expect a decrease in volume. This is a check on the accuracy of our work.

Graph between V and T

The graph between V and T is a straight line as shown in the figure 2.9. If the straight line is extended towards its lower end, it meets at 0. The values of T and V at this point are zero.

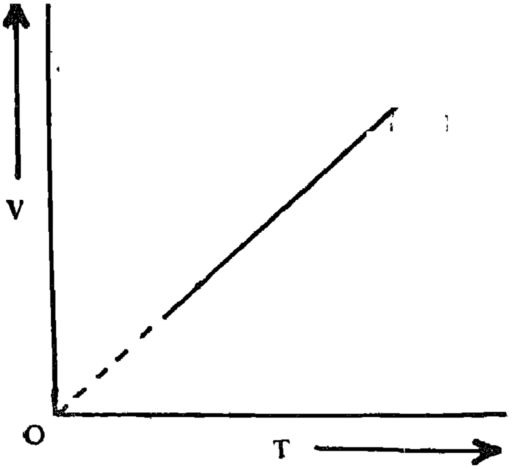


Fig. 2 9 : Varian of volume of a gas with temperature.

Student Activity

Repeat the syringe experiment keeping the same weight on the piston but changing the temperature. Put the syringe in water. Heat water gently. Note the temperatures and levels of piston in the syringe. Plot a graph between V and T.

2 34 Relationship between P, V & T

Gas Equation

Sometimes the volume of a gas is to be predicted after changing both temperature and pressure. Boyle's law or Charles law as such can not be used in the solution of such problems. The relationship between pressure, volume and temperature can be obtained by combining Boyle's law and Charles law.

Assume that the original volume, pressure and temperature of a gas are V_1, P_1 and T_1 respectively and the new volume, pressure and temperature of a gas are V_2, P_2 and T_2. In order to derive the relation between P, V and T, suppose we change the temperature from T_1 to T_2 and keep the pressure P_1

constant. According to Charles law the corresponding volume V' is given by

$$\frac{V_1}{T_1} = \frac{V'}{T_2} \qquad \text{—(i)}$$

$$V' = \frac{V_1 \times T_2}{T_1} \qquad \text{—(ii)}$$

Suppose we now change the pressure from P_1 to P_2 keeping the temperature T_2 constant

Applying Boyle's law

$$P_1V' = P_2V_2 \qquad \text{—(iii)}$$

Substituting the value of V' from (ii), we get,

$$\frac{P_1 \times V_1 \times T_2}{T_1} = P_2\ V_2 \qquad \text{—(iv)}$$

or

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \qquad \text{—(v)}$$

This is known as gas equation.

2.33 Calculations based on gas laws

Example—1

During an experiment 500 c.c. of a gas are collected at a temperature of 20°C and a pressure of 790 mm. What volume would this gas occupy at 0°C and 760 mm. pressure ?

Solution

V_1=500 c.c.
T_1=20+273=293 K
P_1=790 mm
V_2= ?
T_2=0°C=273+0=273 K
P_2=760 mm.

Applying the gas equation

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$V_2 = \frac{P_1V_1 \times T_2}{P_2 \times T_1} + \frac{790 \times 500 \times 273}{760 \times 293}$$

V_2=484 c.c.

Example—2

A gas occupies a volume of 5 litres at 0°C. What will be its volume at 20°C ?

Solution

$V_1 = 5$ litres

$T_1 = 0°C = 0 + 273 = 273$ K

$V_2 = $?

$T_2 = 20°C = 20 + 273 = 293$ K

According to Charles law,

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Then, $V_2 = \dfrac{V_1 \times T_2}{T_1}$

On substituting the values of V_1, T_1 and T_2 we get,

$$V_2 = \frac{5 \text{ lit.} \times 293 \text{ K}}{273 \text{ K}} = 5.36 \text{ litres.}$$

Questions

1. Name and state the law which tells the relation between volume and pressure of a gas at constant temperature.
2. How does the volume of a gas vary with temperature at constant pressure? Name and state the law.
3. Why does a balloon filled with air get smaller in size when kept in cold water ?
4. Oxygen boils at—183°C. What is this temperature on the Kelvin Scale ?
5. A gas expanded at constant temperature from a volume of 300 c.c to a volume of 1 litre, where its final pressure is 250 mm. of mercury. What was its original pressure?
6. A quantity of a gas is found to have a volume of 500 c c. when the barometer is at 750 mm and the temperature is 20°C. The next day, the barometer is at 735 mm and the temperature is 20°C. What is the new volume ?

IV. Home Assignment

1. Why do solids, liquids and gases differ with regard to shape and volume ?

2. How many mole atoms of sulphur and oxygen are present in one mole of H_2SO_4 ?

3. State and explain Boyle's Law.

4. (a) Derive the gas equation.

   (b) A gas occupies a volume of 5 litres at 0°C. What will be its volume at 20°C. (assuming pressure being constant) ?

5. Calculate the number of moles of potassium chloride present in one litre of a solution whose strength is 7.45 grams per litre.

V. Self Asscssment

1. Blow into a balloon and firmly tie its mouth. Place it in cold water for some time and then take it out. Note the change if any. Now repeat the same operation by placing the balloon in water. How do you account for these changes (if any) ?

2. What will be gram molecular mass and gram molecular volume at S.T P. of one mole of ammonia ? What will be the number of particles contained in one mole of ammonia ?

3. State and expalin Charles law.

4. A given quantity of a gas occupies a volume of 400 c.c. at a pressure of 1 atmosphere. What pressure should be applied on the gas so that its volume is reduced to 320 c.c. (temprature remaining constant) ?

UNIT—2

NATURE AND COMPOSITION OF MATTER—II
TEACHER'S GUIDE

The teacher may emphasise upon the following areas ;

(a) Arrangement/Packing of molecules in solid, liquid and gas.

(b) Mole concept

(c) Mathematical expressions of gas laws and

(d) Derivation of gas equation from gas laws. A few numerical problems based on gas laws may be solved in the class.

Demonstrations/Experiments

Demonstration—I

Packing of molecules in the three states of matter.

Materials required :

4 transparent plastic plates, a piston (made of plastic or thin wood), a small fan, light plastic balls.

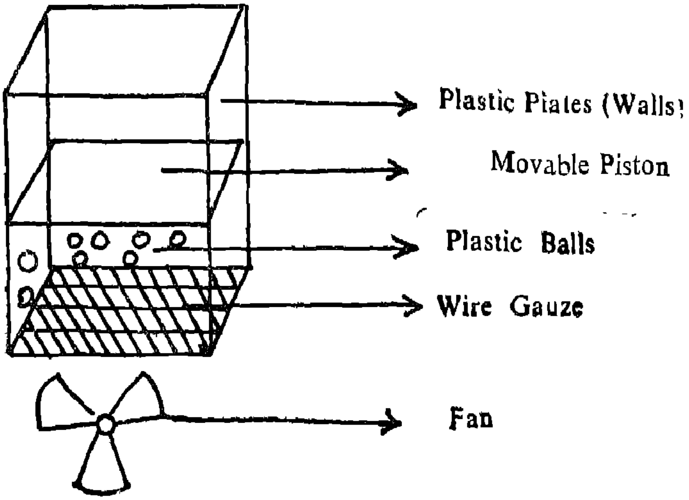


Fig. 2.1

Procedure: The four walls of the box (Fig.2.1) are made of transparent plastic material. The bottom part of this is made up of wire gauze. Inside this, add plastic or polystyrene balls (light in weight). Keep a piston above the balls so that they are kept in a compact position Show this arrangement to the students and emphasise that it represents solid state. Pull the piston up so that there is a little space between plastic balls and the piston. Put the fan under the wire gauze. Due to the blowing of air from the fan, the plastic balls will move upward and than these will come down. Show this situation to the students and compare the same with molecules in the liquid state. The molecules have more space between them and more freedom of movement as compared to solid state. Now, further increase the distance between the piston and plastic balls. Again put the fan at the bottom of the wire gauze The plastic balls will move in a random zig-zag motion. Compare this motion of plastic balls with the movement of molecules in gaseous state.

Remarks

1) An improvised fan can be used (which works with battery). As the speed of this fan can not be controlled, distance between the fan and the wire gauze is adjusted for the liquid and the gaseous states accordingly.

2) Instead of a fan, we can use other methods also. We can do the experiment without using wire gauze. Put a funnel at the bottom so that its tip is connected to the rubber tube. We can pump air through the rubber tube. Pump less amount of air to show the arrangement of molecules in liquid state and more air to show the arrangement of molecules in gaseous state.

Demonstration—2

Molecular motion

The molecular motion in gases may be demonstrated as follows ;

Take a boiling tube or a glass tumbler and put about 0.5 c.c. of liquid bromine in it. Cover the tube with a cork. Leave it undisturbed for some time. After sometime brown vapours of the gas will fill the whole tube.

Warm the tube very gently into warm water. Warming enhances the rate of evaporation of bromine vapours.

Molecular motion in liquids

Take a gas jar and place a crystal (0.5 g) of copper sulphate in it Add about 100 c.c. of water from the side of the jar so that the copper sulphate crystal is not disturbed. After sometime the students can observe the slow and smooth movement of blue colour due to copper sulphate. After a considerable time, next day, the whole solution becomes uniformly blue

Demonstration—3

Dependence of volume on pressure

Materials required: Test tube of a uniform bore (inner diameter) or burette, rubber cork, glass tube, rubber tube connector, syringe, weights (500 g, 1 kg 2 kg) Retort stands.

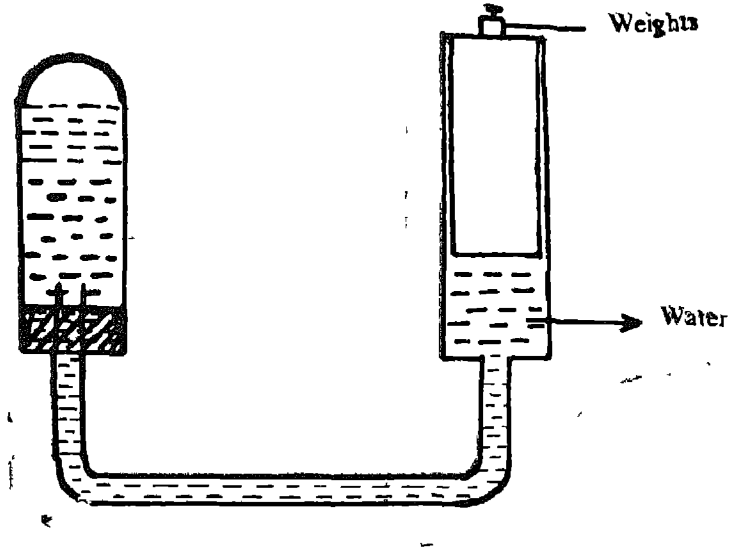


Fig 2.2 : Apparatus for verification of Boyle's law

Procedure : Set up the apparatus as shown in Fig. 2.2. Adjust the water level of tube and piston to have equal pressures.

Keep on putting the weights on top of the piston of the syringe as shown and note the volume indicated in the tube. Note the volumes occupied by the gas using different weights and record the observations in the following table.

TABLE

Sr. No.	Weight	Volume	Weight/Volume
1.			
2.			
3.			
4.			

From the data obtained from the experiment, draw the necessary inferences.

Precautions :

The whole set up of the apparatus should be airtight.

Demonstration—4

Dependence of Volume on Temperature

Materials required : Round bottom flask, Manometer, Thermometer (—10°C to 110°C), spirit lamp, Laboratory stand etc.

Procedure: Set up the apparatus as shown in Fig 2.3. The flask should be supported on laboratory stand by clamps. Gradually heat the flask with help of a spirit lamp. Note the temperature and pressure at various stages. Pressure is read on the manometer attached to the apparatus. Collect the data by varying the temperature and draw appropriate inferences.

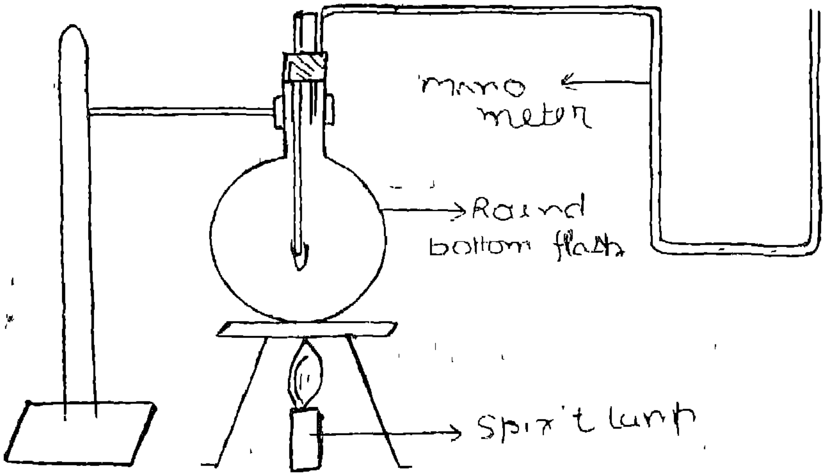


Fig. 2.3 Apparatus to demonstrate relationship between pressure and temperature for a definite mass of a gas.

Precautions : The apparatus should be airtight.

UNIT—2

ASSESSMENT - I

1. Describe the difference in solids, liquids and gases in terms of inter molecular forces.

2. Calculate the mass in grams of 5 moles of carbon dioxide.

3 How does the pressure of a gas varies with its volume at a constant temperature ? State the law which governs this. Describe a method to variefy this law. Draw the shape of the graph when P is plotted versus $\frac{1}{V}$.

4. The volume of oxygen gas at 23°C and 700 mm pressure is 200 c c. Calculate the volume of oxygen gas at S.T.P.

5. Calculate the number of moles in 49 grams of H_2SO_4.

ASSESSMENT - II

1. (a) What is meant by states of matter ?

   (b) Why does a balloon expands when it is filled with air ?

   (c) On the basis of intermolecular arrangement, describe the difference between solid, liquid and gas.

2 Define mole in terms of number of particles, molecular mass and molar volume.

3. State Avogadro's law and apply it to calculate volume occupied by 11 grams of carbon dioxide at S.T.P.

4. A given mass of a gas occupies 800 c c when the pressure on the gas is 1 atmosphere & the temperature is 273 K. What will be the volume of the gas when pressure is 1.25 atmosphere and the temperature is 323 K.

5 A solution contains 3.12 grams of cane sugar ($C_{12} H^{22} 0_{11}$) per litre of solution What is its molar concentration ? (Atomic Mass of C=12, H=1 and 0=16)

UNIT—2

ASSESSMENT - III

1. Compare the movement of particles in a solid with movement of particles in a gas at a given temperature.

2. Calculate the mass of one mole of water.

   (Atomic mass of H=1, 0=16). How many water molecules are present in it ?

3. Explain the effect of changing

   (i) Pressure

   (ii) temperature

   On the volume of gas respectively.

   Explain the relationship between

   (i) Volume of a gas and its pressure (T constant).

   (ii) Volume of a gas and its temperature (P constant).

4. A gas, volume 20 litres, is cooled at constant pressure from 100°C to 0°C. What volume will it occupy at 0°C ?

5. 500 c.c. of caustic Soda solution contains 100 grams of NaOH in it. What is molar concentrition of solution ?

ASSESSMENT - IV

1. In a balanced equation :
   $CH_4(g)+2O_2\ (g) \longrightarrow CO_2\ (g)+2H_2O\ (l)$

   (a) How many moles of methane will be required to obtain 8 moles of water ?

   (b) How many grams of CO_2 will be obtained if you start the reaction with one mole of methane ?

2. State Boyle's law How can it be verified experimentally

3. 100 c c. of a gas at 10°C is heated to 20°C at constant pressure. Calculate the new volume of the gas.

4. You have a solution of 0.1 M Na_2CO_3 How many c.c. of this solution would contain 5.3 grams sodium carbonate ?

UNIT—2

ASSESSMENT - V

1. (a) Why are gases so easily compressible whereas it is almost impossible to compress a solid or a liquid ?

   (b) What do you understand by Avogadro's number ?

   (c) Which will have greater number of molecules in it—10 g of O_2 or 10 g NH_3 ?

2. 1 gram of a gas has a volume of 0.45 litres at STP. What is the molecular mass of the gas ?

3. Explain the following terms in brief ;

   (i) gram molecular volume

   (ii) Standard temperature pressure

   (iii) molar concentration and

   (iv) mole.

4 Derive a mathematical relationship between pressure (P), volume (V) and temperature (T) of a gas when P is changed from P' to P'', V from V' to V'' and T from T' to T''.